Original Research

Surgeon-placed peripheral nerve block and continuous non-opioid analgesia in total knee arthroplasty is accessible intraoperatively: A cadaveric study

Daniel Matthews a,b,1, Robert T. Rella c,*

a Alabama Orthopedic Sports Medicine, Daphne, AL 36526, USA
b University of South Alabama Department of Orthopedic Surgery, 36617, USA
c University of South Alabama Frederick P. Whiddon College of Medicine, 36688, USA

ARTICLE INFO

Keywords:
(MeSH): nerve block
Nerve blocks
Postoperative pain
Total knee replacement

ABSTRACT

Background: Pain management in TKA patients is challenged by a postoperative requirement for early ambulation along with the concurrent goal of reducing opioid consumption while simultaneously reducing the length of hospital stay. Peripheral nerve blocks (PNB) address these concerns to some degree, with femoral nerve and adductor canal blocks being the most-used regional nerve blocks for surgeries performed around the knee joint.

Purpose: The authors hypothesized that placing a catheter between the muscles that make up the adductor canal during a standard surgical approach for a Total Knee Arthroplasty would provide equitable or superior access for a peripheral nerve block in the adductor canal. The nerves that are located between the muscles that make up the adductor canal transmit the majority of the pain after TKA.

Methods: This cadaveric study was conducted in 12 fresh-frozen human cadaveric lower limbs, comparing the standard technique of adductor canal block, placed under ultrasound guidance, to this experimental technique. Using colored indicator dyes to locate the site of surrogate peripheral nerves, the techniques were compared.

Results: Through a standard anterior surgical approach to the knee, an intraoperative catheter placement technique can be performed to provide a peripheral nerve block to the saphenous nerve in the adductor canal. The nerves that are located between the muscles that make up the adductor canal transmit the majority of the pain after TKA.

Conclusions: This cadaveric study demonstrates the availability for the surgeon to place a catheter between the muscles that form the adductor canal during a standard surgical approach for TKA. This novel technique can provide equivalent coverage of the nerves for an ACB when compared to a standard ultrasound guided ACB.

What are the new findings?

- The adductor canal is accessible through gentle blunt dissection when the knee is exposed through common surgical approaches to the knee joint.
- Performing an adductor canal block intraoperatively through a standard surgical approach to the knee allows the surgeon to consistently access the same anatomic structures as an ultrasound guided adductor canal block.
- Performing an adductor canal block intraoperatively allows for the placement of an indwelling catheter to deliver extended, continuous analgesia.
- Performing an adductor canal block intraoperatively through the surgical approach has the potential added benefit of affecting the obturator nerve not relegalized with the ultrasound guided adductor canal block.

Introduction

Total knee arthroplasty (TKA) is considered one of the most painful medical procedures that is routinely performed today [1,10,11]. Pain management in TKA patients is challenged by a postoperative requirement for early ambulation along with a concurrent need to reduce opioid consumption and hospital stay. Peripheral nerve blocks (PNB) address these concerns to some degree, with femoral nerve block (FNB) and adductor canal block (ACB) being the most used analgesic modalities to treat post-TKA pain [20,24]. However, the optimal PNB or combination of blocks remains unclear [1,24,2]. There is a growing body of evidence suggesting that ACB provides analgesic effects comparable to FNB but without causing a motor blockade, which is associated with a high risk for falls [20,4,24]. The ACB is typically placed by an anesthesiologist.
prior to TKA, which inevitably leads to consumption of valuable time, resources and leads to increased costs. Moreover, the exact anatomical location of ACB is still debated among anesthesiologists, leading to a variable pain relief [2,21]. The adductor canal is a musculopneumoretic tunnel that originates at the apex of the femoral triangle in the mid-thigh and extends to the adductor hiatus [13]. The canal is formed by the vastus medialis muscle anteriomedially, the sartorius medially and vastoadductor membrane (VAM) providing the “roof” over the adductor longus and magnus muscles posteriorly [2,21,6,19]. Given the anatomy of the adductor canal itself, there is a rationale for an alternative ACB placement at the time of TKA. It is also of potential benefit to the patient to perform the ACB intraoperatively as it eliminates the need for another provider to perform an additional procedure on the patient, as well as the unique opportunity to place an indwelling catheter for extended pain relief. The authors propose that the saphenous nerve passing through the adductor canal can be blocked during a TKA procedure, by placing a catheter between the muscles that form the borders of the adductor canal. Herein, the authors performed a cadaveric study to evaluate the feasibility of an intraoperative catheter placement by the operating surgeon, to deliver a continuous adductor canal and periarticular block for treating post-TKA pain. Some of the present results were published in the abstract form [15]. The purpose of this study was to investigate the safety and accessibility of performing an ACB intraoperatively with placement of an indwelling catheter to provide extended pain relief not available through ultrasound guided single shot blocks alone.

Methods

**Cadaveric tissues**

This study was conducted in 12 fresh-frozen human cadaveric lower limbs (T12 to toes) in compliance with all local, state, and federal regulations, and under the policies and guidelines of the anatomical laboratories at SUNY Upstate Medical University (Syracuse, NY) and the Atlanta Medical Center (Atlanta, GA). None of the cadavers had a documented history of surgeries involving the knee or femur. The limbs were allowed to thaw for 24 hr prior to use and all dissections were performed according to the Cunningham’s Manual of Practice Anatomy [13]. The primary endpoint tracked was which nerve(s) were stained with each approach and the secondary endpoint was the region of overlap between the two methods.

**Comparison of pre-operative and intraoperative ACB placement**

Dissections were performed to compare the results of an ACB using the pre-operative ultrasound guided anesthesia technique and the novel intraoperative surgeon-placed catheter delivery technique to identify and track the course of the saphenous nerve with its infrapatellar branches, the nerve to the vastus medialis, and the obturator nerves. Each limb was carefully dissected after allowing the respective dyes to stain tissue for approximately 15 min.

To reveal the region of tissue staining resulting from each respective dye injection technique, dissection was started proximally at the level of the femoral triangle in the mid-thigh to the entry point of the standard ACB catheter and extending medially and caudally to the tibial tuberosity. The sartorius muscle was reflected medially and the adductor canal structures were identified. Careful dissection exposed the vastus medialis, the obturator nerve (anterior and posterior), the medial and the intermediate femoral cutaneous nerves and the tibial nerve (posterior articular branch). All nerves were identified, and the position of each infusion catheter was confirmed. The dye staining the above nerves of interest were observed and recorded.

**Preoperative and intraoperative adductor canal nerve block placement**

To evaluate the ability to appropriately place a novel ACB intraoperatively, a comparison was made between this novel placement and a standard preoperative ACB using standard ultrasound guided anesthesia techniques. This comparison was performed using saline solutions of different colors as surrogates for the nerve block solution. Using the same human cadaveric limb, the resultant location of tissues stained with the colored saline following both ACB techniques would serve to indicate whether use of the novel ACB technique would be able to serve as an appropriate ACB. The traditional preoperative block was performed initially using the standard ultrasound technique and this was followed by the novel intraoperative surgeon placement technique performed through a standard para patella approach to the knee, that is commonly used in TKA. This was performed in all 12 specimens with equal amounts of fluid.

**Preoperative catheter placement technique**

First, 5 mL of a green-colored saline solution was injected into the adductor canal using the standard preoperative technique via a standard syringe and needle under ultrasound guidance. This was placed at the level of the mid-thigh 9–16 cm distal to the apex of femoral triangle as described by Bendtsen and colleagues [2,21]. The green dye was used to mark the tissues infiltrated at the needle tip site of injection. This ACB was placed prior to the TKA surgical approach. The site of injection is shown in Fig. 1. This technique is commonly used by anesthesiologists and other practitioners in clinical practice prior to knee surgery. A standard medial parapatellar approach to the knee was performed by a surgeon who routinely performs TKA and the novel ACB procedure in clinical practice. The anatomical landmarks of the surgical approach are shown in Fig. 1. First, the skin covering the patella was incised from a point 2-finger breadths (approximately 3 cm) cephalad to the superior patella and extending down to the tibial tubercle. The vastus medialis oblique (VMO) muscle was then located medially, and an incision was made detaching the VMO from the patella leaving a cuff of capsular tissue on the patella for closure.

After completion of the standard parapatellar approach to the cadaver knee specimen, as noted above, the steps to perform the novel ACB were carried out as listed in Table 1.

The pertinent anatomical landmarks are shown in Fig. 2. After placement of the catheter (See Table 1), 5 mL of a blue colored saline dye was injected through the catheter to identify the tissue infiltrated with this placement. All cadavers were injected with the same amount of dye for each approach. The blue dye injected here stained the structures that could be accessed by the surgeon intraoperatively.

**Anatomical landmarks in limb specimens following block placement**

In all limb specimens, there was no pathology or overlying surgical scars identified in the areas of interest. Detailed dissection revealed the fascial layers of the medial intermuscular septum were attached to the shaft of the femur proximally while at the adductor tubercle, the septum was seen to be continuous with the adductor magnus tendon. This post-catheter placement dissection revealed the catheter placed using the intraoperative technique using a medial parapatellar approach to the knee, was consistently located along the anterior surface of the medial intermuscular septum (Fig. 2). The position of the infusion catheter placed using the preoperative ultrasound guided ACB block technique was slightly distal to the apex of the femoral triangle posterior to the septum. Following retraction of and or removal of the sartorius muscle, both catheters were reproducibly found within the tunnel formed by muscular borders of the adductor canal and the VAM. The VAM in the majority of examined specimens had a slightly rhomboid shape, being wider proximally and was visualized as a thin, fibrous tissue that was stretched between the vastus medialis muscle and the anterior surface of the adductor longus muscle. Distally, it was thicker and connected to the tendinous fibers of the adductor magnus tendon and the medial intermuscular septum (Fig. 3). Note the probe placement in Fig. 3 with the medialis being retracted back. In addition to the dissections of the saphenous nerve, the nerve to the vastus medialis, the anterior and posterior obturator nerves,
the medial and the intermediate femoral cutaneous nerves were identified in all specimens. These structures are masked in Fig. 3 due to the VAM.17.

Results

This cadaveric study demonstrated that a standard surgical approach to the knee provides an excellent exposure to the medial intermuscular septum making up the floor of the adductor canal. Through this standard surgical exposure, this intraoperative catheter placement technique provides access to perform a peripheral nerve block for patients undergoing TKA. Our examination of the area of interest demonstrated that the Surgeon placed catheter was consistently placed atop of the medial intermuscular septum adjacent to the musculoaponeurotic tunnel known as the adductor or Hunter’s canal.

Dye staining location observed during dissection

Table 2 summarizes the nerve structures stained by the dyes injected via standard ACB and via intraoperative surgeon-placed catheters. All the nerve branches innervating the knee joint were identified, specifically noting the dye spread related to the saphenous and obturator nerves as these two nerves transmit most of the pain response related to TKA. The green dye from the Ultrasound guided ACB block (Fig. 3A) was detected mostly in the adductor canal and consistently stained the saphenous nerve. The blue dye staining from the intraoperative surgeon catheter placement (Fig. 3B) was found to intensively stain the medial intermuscular septum, the VMO, the saphenous nerve and the nerve to the vastus medialis muscle. Co-localization of stain from the two different block techniques was observed at the saphenous nerve as well as the nerve to the VMO.

Table 1

<table>
<thead>
<tr>
<th>Procedure Steps</th>
<th>Step-by-step instructions on intraoperative catheter placement technique during TKA procedure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>Procedure</td>
</tr>
<tr>
<td>1</td>
<td>Elevate the VMO with blunt retractors (army/navy) at the level of the patella to expose its deep surface and the anterior surface of the intermuscular septum.</td>
</tr>
<tr>
<td>2</td>
<td>Identify adductor tubercle of the epicondyle of the femur and place an index finger on it.</td>
</tr>
<tr>
<td>3</td>
<td>Identify the anterior surface of the medial intermuscular septum by sliding your finger from the adductor tubercle proximal along this intermuscular septum. The intramuscular septum represents the &quot;floor&quot; for catheter placement.</td>
</tr>
<tr>
<td>4</td>
<td>Using blunt digital dissection with a gloved finger, this potential space is dilated by passing the finger along the femoral shaft, progressing proximally 8–10 in underneath the VMO just anterior and on top of the medial intermuscular septum.</td>
</tr>
<tr>
<td>5</td>
<td>Pass the introducer needle and T-pee sheath through the skin from the superior lateral aspect of the knee, just above the joint at the superior pole of the patella. Pass the needle under the rectus femoris muscle and advance the needle into the space created under the retracted VMO.</td>
</tr>
<tr>
<td>6</td>
<td>Remove the introducer needle leaving the T-pee sheath in place. Pass the catheter (1-mm diameter infusion soaker catheter) through the T-pee sheath and retrieve by pulling the entire length of the catheter into this space.</td>
</tr>
<tr>
<td>7</td>
<td>Peel the T-pee sheath away and discard it.</td>
</tr>
<tr>
<td>8</td>
<td>Grasp the distal end of the catheter with a smooth straight-tipped pituitary rongeur (8 in) and advance it 8–10 in cephalad through the space created by the blunt dissection. This space is just medial to the femoral shaft and along the anterior surface of the medial intermuscular septum just deep to the VMO. Using your finger pinch the catheter to the medial femoral metaphyseal flare while opening the jaws and slowly remove the rongeur leaving the catheter in place.</td>
</tr>
</tbody>
</table>
In addition to the dye staining these two nerves, the muscles forming the muscular boarders of the adductor canal, the medial intermuscular septum, the vastus medialis, and the adductor magnus were all also heavily stained by the dye. The surgeon placed ACB also revealed staining of the posterior branch of the obturator nerve. While the catheter, placed by the surgeon was not directly in contact with the saphenous and obturator nerve branch, being separated by the septum, these nerves were heavily stained using the surrogate surgeon block placement. This indicated that the septum was permeable for the dye.

**Discussion**

This cadaveric study demonstrates the availability for the surgeon to place a catheter between the muscles that form the adductor canal during a standard surgical approach for TKA. This novel technique can provide equivalent coverage of the nerves for an ACB when compared to a standard Ultrasound guided ACB. These nerves that are located between the muscles that make up the adductor canal transmit the majority of pain after TKA.

Innervation of the knee is known to be mediated by branches of multiple (femoral, saphenous, obturator, common peroneal, and tibial)

---

**Fig. 2.** Anatomical landmarks for novel intraoperative catheter placement for adductor canal block (ACB).

**Fig. 3.** Staining of tissues following use of colored saline as surrogate for nerve block solution during preoperative adductor canal block (ACB) (A) and intraoperative surgeon placed block (B). Green dye was used for the preoperative technique and blue dye was used for the intraoperative technique. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

**Table 2**

Nerves stained during standard preoperative and novel intraoperative ACB. The staining location associated with both block techniques was found to be similar. The novel surgeon placement however did uniquely stain the posterior branch of the obturator nerve.

<table>
<thead>
<tr>
<th>Stained nerve</th>
<th>Saphenous</th>
<th>Nerve to vastus medialis</th>
<th>Medial femoral cutaneous</th>
<th>Intermediate femoral cutaneous</th>
<th>Anterior obturator</th>
<th>Posterior obturator</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACB (preoperative)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Intraoperative</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>
nerves [18], with 45%–80% of nerve fibers in the knee being identified as nociceptors [3]. Therefore, there is an evident anatomical rationale for treating post-TKA pain from within the knee. Periarticular blocks are commonly performed by the surgeons and are used either to supplement anesthesiologist placed continuous ACB or as part of multimodal pain management following TKA [9,16,12,8]. They are typically administered as single injections (of variable compositions and volume) at the time of surgery but do not provide a long-lasting (greater than 24 hr) analgesic relief [1]. This periarticular block technique (capsular injection) has gained popularity as an adjuvant approach in treating post operative pain in TKA. While this capsular injection PNB is associated with a low incidence of adverse events, the optimal volume and composition of the analgesic agents remains unclear and was not examined in this study [1].

It has also been shown that when an ACB is performed in addition to intra-articular analgesia there is a reduction in average pain reporting, an increase in the amount of pain free time after TKA, and a reduction in the number of requests for morphine rescue analgesia [14]. Given multiple innervations of the knee as well as considerable variability in the nociceptor distribution and density among individuals, the authors believe in addition to the PNB, our surgeon placed ACB with continuous catheter infusion of non-narcotic analgesic targeting the adductor canal allows the surgeon to deliver continuous long-lasting periarticular analgesia.

All cadaveric dissections in our study were conducted in agreement with previous reports [6,19,17]. The end of the catheter was placed approximately 17 ± 3 cm cephalad from the superior pole of the patella laying along the anatomical location identified as the medial intermuscular septum. This septum, serving as the floor for catheter placement, is a partition of the deep surface under the vastus medialis between the knee extensor and adductor muscle groups [5,13]. Distally, at the level of the adductor tubercle, the medial intermuscular septum is continuous with the adductor magnus tendon which is palpable just cephalad to the tubercle. Together with the other two—lateral and posterior—septa of the thigh, the medial intermuscular septum attaches to the peristeum of the femoral bone at the linea aspera [13,22]. With some variations the vessels and nerves supplying the muscles in these compartments form neurovascular bundles located inside their own conical or tubular muscular-fascial tunnel [25]. Indeed, the medial intermuscular septum has been shown to have up to 8 perforating vessels - three arteries and five veins—organized in a predictable fashion [18]. Each of the piercing zones can provide a passage for dye/analgesics to infuse into the canal.

Noteworthy, the authors generally observed more dye peri-articular to the knee after the knee flexion-extension maneuvers were performed to mimic the post-surgical range of motion of TKA patients. This was noted even when a small dye volume was delivered via a single injection using the surrogate surgeon placement. A previously published fluoroscopic in vivo study on the extent of contrast spread with a continuous catheter infusion in patients undergoing TKA has also revealed that the contrast injected at low pressure can spread in both cephalad and caudal directions [7,23]. The overlap of the two staining methods can be seen in a cadaveric knee (Fig. 4).

The ACB is becoming a standard of care for TKA patients by providing analgesia comparable to the effects of FNB but without the risk of a motor blockade which is associated with an increased risk of falls [20,4,24]. The ACB is typically placed by an anesthesiologist prior to TKA. The exact anatomical location of this ACB varies among anesthesiologists [2,21]. When compared to an ultrasound guided standard ACB placed in accordance with Bendtsen et al. recommendations [2,21], the intra-operative surgeon placed block co-stains the saphenous nerve. This co-staining of the saphenous nerve indicates that similar analgesic effects can potentially be obtained whether the catheter is placed by an anesthesiologist under ultrasound guidance or the surgeon using the technique described.

We were able to demonstrate that the surgeon-placed approach has the added benefit of staining the posterior branch of the obturator nerve, which potentially may provide more pain relief under the premise that blocking more nerves that innervate the knee should provide more pain relief. As confirmed by these cadaveric dissections, the catheter placement along the anterior surface of the medial intermuscular septum appears to be safe and reproducible. The placement variability is diminished by the well-defined muscular margins; the vastus medialis anteriorly, the femoral shaft laterally and the septum lying just anterior to the adductor magnus/longus posteriorly. This anatomical area is well anterior to the femoral artery and femoral vein.

Our surrogate intraoperative catheter placement resulted in additional spread of the dye into the posterior-medial knee region. Although the amount of dye spread to the knee was not controlled, it can be speculated that this surgeon-placed block can benefit periarticular analgesia as well during the postoperative course as the patient ambulates and gravity pulls analgesia inferriorly towards the knee. In contrasted from the ultrasound guided ACB a surgeon placed ACB with indwelling catheter will potentially continue to supply analgesia to the joint for days after surgery.

The results of this study demonstrate that standard approaches to TKA provide excellent exposure to the medial intermuscular septum adjacent to the adductor canal, and the opportunity for a surgeon to place an intraoperative catheter within the adductor canal for extended post-TKA pain relief.

Based on our findings associated with this cadaveric study, our surgeon-placed novel PNB technique has proven to provide a viable option that may lead to a reduction in the utilization of opioid analgesia. This PNB can be delivered by the operating surgeon during medial parapatellar, sub-vastus, and mid-vastus TKA approaches. Because these blocks are performed by the surgeon during the normal flow of the operation, it eliminates an additional anesthesia procedure, implicating the potential to reduce operative time and costs. While this study does not report clinical data, it highlights the opportunity for future studies to analyze the safety, efficacy, and effectiveness of a surgeon placed ACB with indwelling catheter placement in TKA.

This study has accepted limitations related to being a cadaveric study, understanding that in vivo tissue may have differing properties that can alter the precise location of analgesia delivery. This study is limited in that the data reported here are qualitative in nature and do not provide a strong quantitative basis on which to draw definitive conclusions. Another limitation of the study is that the procedures performed on the cadaveric specimens were performed by an experienced surgeon, and results may vary depending on surgeons’ experience.

Conflict of interest statement

The principal author is an independent consultant to Avanos, Smith & Nephew, Johnson & Johnson. There are no conflicts of interest concerning the work performed for this project.
Funding

This research received support from Avanos and SUNY Upstate Medical University for the cadaveric dissections related to this project.

Declaration of interests

The authors declare the following financial interests/personal relationships that may be considered as potential competing interests:

Daniel Matthews reports financial support was provided by Avanos. Daniel Matthews has patent # 20200316345 with royalties paid to Daniel Matthews.

Acknowledgments

The study was funded by Avanos Medical, Inc (Alpharetta, GA). Avanos supplied the catheters which are proprietary and provide educational materials copyrighted by author relating to this technique. No ethics approval was required for this study as well as no institutional review board approval was required.

References


